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Disturbance influences the invasion of a seagrass into an existing meadow

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ABSTRACT

Future impacts from climate change and human activities may increase the likelihood of invasions of native marine species into existing habitats as a result of range shifts. To provide an understanding of the invasion of a native seagrass species (*Syringodium isoetifolium*) into a tropical multi-species meadow, detailed field assessments were conducted over a six year period. After establishing in a discrete patch, the extent and standing crop of *S. isoetifolium* increased 800 and 7000 fold, respectively, between 1988 and 2003 (~300–260,000 m^2 and <1 kg DW to 7596 ± 555 kg DW). The expansion of *S. isoetifolium* was confined to subtidal areas and appears primarily from clonal growth. The observed expansion of this species into a new locality was found to be clearly influenced by cumulative impacts and chronic small-scale physical disturbances. This study has immediate relevance to managing impacts which influence the spread of invasive species.

1. Introduction

Predicating species responses to environmental change requires knowledge not just of their physiology and their interactions with other existing species, but also of new interactions with species that are invading due to range shifts (He et al., 2013; Rahel and Olden, 2008). Given the increasing likelihood of species geographic range shifts due to environmental change (McCarty, 2001) the capacity to understand the consequences of these shifts in terms of the resultant species interactions is of wide reaching importance.

An invasive species can affect ecosystem structure, functioning and resultant provision of ecosystem services through changes such as habitat availability, associated biota, and biogeochemical cycling (Pejchar and Mooney, 2009; Vicente et al., 2013). As a result of such changes, biological invasions in many ecosystems have resulted in major biodiversity loss (Bax et al., 2003; Butchart et al., 2010) and are generally considered a threat to the integrity of natural communities and to the preservation of endangered species (Walker and Kendrick, 1998; Lodge, 1993; Carlton and Geller, 1993; Ribera and Boudouresque, 1995; Vitousek et al., 1997). Not all species invasions result in biodiversity loss as new species interactions induced by an invasion can have positive effects upon that system. In natural communities, species have been found to affect each other through both negative and positive interactions (He et al., 2013).

Invasive plants are recognised as species or strains that rapidly increase their spatial distribution by expanding into existing plant communities (Kercher and Zedler, 2004). Although some invasions simply result from natural or human induced dispersal mechanisms, providing an invader species the opportunity to rapidly out-compete existing species, a range of biological and physical factors can drive such processes (Bax et al., 2003; He et al., 2013; Williams, 2007). For example, physical disturbance can provide an opportunity for an invasive species to have a competitive advantage (Williams, 2007) which may depend upon the life history traits of the invasive species and the interactions of that species with native species (He et al., 2013).

Tropical seagrass meadows are characterised by high disturbance regimes which can occur at a range of scales and are thought to be of importance in driving species composition and interactions (Carruthers et al., 2002; Rasheed, 2000). Such disturbance can be ecophysiological (e.g. light limitation, elevated nutrients) or physical (e.g. grazing, bioturbation, waves) (Larkum et al., 2006). Physical disturbance is common and has multiple forcing factors including both natural and human related (Williams, 1988; Preen et al., 1995; Creed and Amado Filho, 1999; Kenworthy et al., 2002). Physical disturbances may cause seagrass loss (Orth et al., 2006a; Waycott et al., 2009) or through subsequent recovery

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processes, can lead to changes in seagrass species and structural composition (Birch and Birch, 1984; Preen, 1993; Campbell and McKenzie, 2004). These drivers of change may occur over a range of spatial and temporal scales such that impacts from some disturbances may not be immediately apparent.

Although relatively rare, changes to seagrass meadows have been associated with the spread of invading introduced seagrass species (Posey, 1988; Larned, 2003; Bando, 2006; Williams, 2007). Specific examples of this are the invasion of *Zostera japonica* into the Pacific NE (Harrison, 1982). Given the proposed scenarios of future environmental change, such phenomena are likely to increase in prevalence as geographic ranges change. Given the continued global declines of seagrass, understanding factors that may drive further change is of importance to their conservation and management. Detailed examples of how a marine species such as seagrass naturally expands its range into new localities and the resultant inter-species dynamics are rarely documented and hence poorly understood and have the capacity to provide inferences about future invasions.

Syringodium isoetifolium has a wide Indo-Pacific distribution and inhabits sandy substrates in shallow waters often associated with reef platforms (Green and Short, 2003). It often occurs in multi-species meadows and is usually considered a competitor species for its ability to rapidly recolonise disturbed areas (Birch and Birch, 1984; Rollon et al., 1998). Here we document the expansion in extent and standing crop (above ground biomass) of a native seagrass *S. isoetifolium* since its first record at a new tropical locality. We discuss the competitive ability of this species, and the role that disturbance, both natural and anthropogenic, may have contributed to its apparent introduction and expansion.

2. Methods

Green Island is a vegetated coral cay located situated approximately 27 km north-east of Cairns (16°46′S, 145°58′E), within the Great Barrier Reef (GBR) Marine Park and World Heritage Area (Fig. 1). It is an inner shelf planar reef (about 710 ha) orientated north-west–south-east extending approximately 4 km along its longest axis and 2 km along its shortest axis. A shallow and indistinct lagoon on the north and north-west lee of the cay gently deepens to the back-reef slope (Beach Protection Authority, 1989).

Green Island tides are diurnal with a mean sea level of 1.54 m and a mean lower low water at 0.6 m above Australian Height Datum (Department of Transport, 2006). Winds from the south-east predominate throughout the year, strongest during winter but weaker and with a north easterly element in summer months (Maxwell, 1968).

Seagrasses at Green Island were first described in October 1967 (den Hartog, 1970) and increases in their distribution have been a topic of debate for many years (den Hartog, 1970; Kuchler, 1978; Udy et al., 1999; Hopley, 1982, 1989; Gourlay, 1983; Van Woesik, 1989; Wolanski, 1994; Brodie, 1995). The first detailed examination of the seagrass meadows on Green Island was from May 1987 to April 1988 (Mellors and Marsh, 1993; Mellors et al., 1993). The most abundant seagrass meadows (dominated by *Halodule uninervis* with *Cymodocea serrulata, Cymodocea rotundata* and *Halophila ovalis*), were located in the lagoon on the sheltered north-western side of the cay. Less abundant meadows (dominated by *Thalassia hemprichii* and *C. rotundata*) were reported on the reef flat located on the north-eastern and southern sides of the cay. Although *S. isoetifolium* is reported throughout the GBR region, on Green Island it was rare and only a few plants were found in early 1988 (Baxter, 1990).

Detailed mapping of seagrass distribution was conducted in 1992, 1993, 1994, 1997 and 2003 from August and September of each year, to factor out seasonal variation (see McKenzie, 1994). Points were systematically mapped every 20 m along permanent north–south orientated transects (100–1000 m in length), located 100–500 m apart, each year (Fig. 2). A theodolite and/or differential

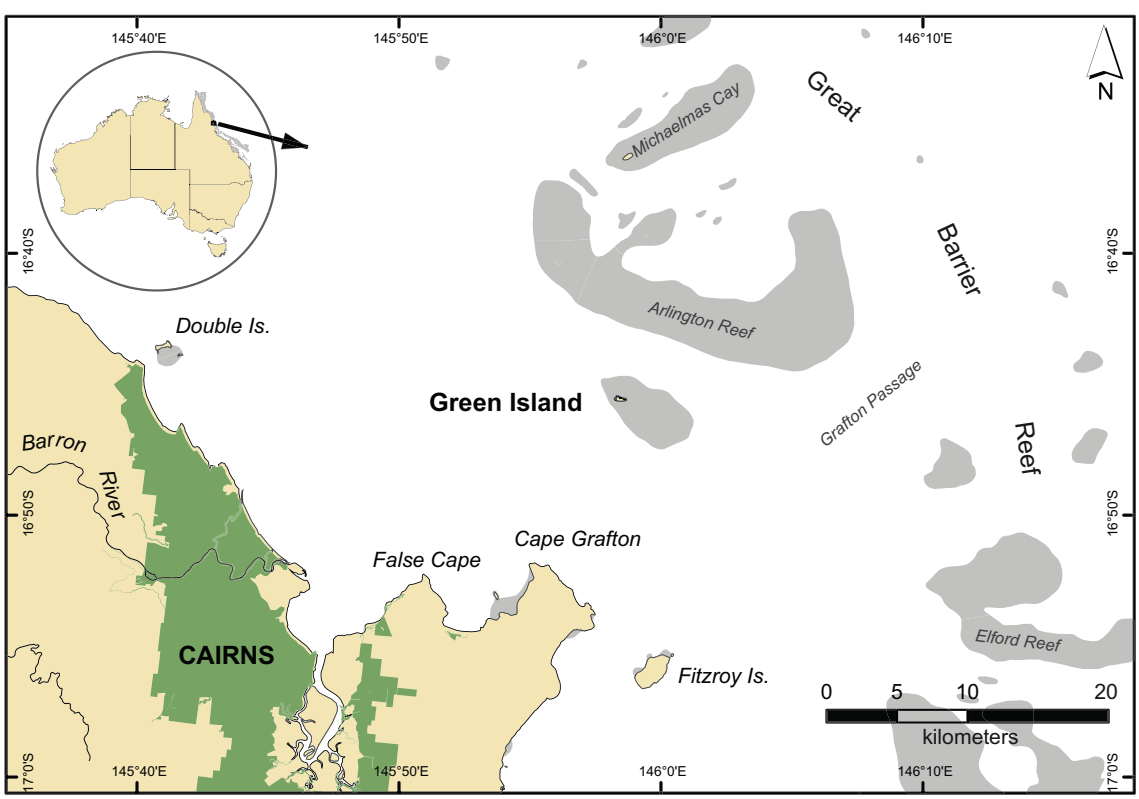

Fig. 1. Green Island is located 27 km NE of the Australian mainland in the middle of the Great Barrier Reef lagoon.